South Palm Beach County Ground Water Flow Model

Introduction

The South Palm Beach County ground water flow model is the third in a series of models developed for the SAS within Palm Beach County. The first models were developed by Shine, et. al. (1989) and used to assess the ground water resources of eastern Palm Beach County. In particular, this effort involved the development and application of two models: one for the northern portion of the county (north of the C-51 Canal) and the other for the southern portion (south of the C-51 Canal). A second version of the model was developed by Yan, et al. (1993) in which the two models for the northern and southern portions of the county were combined into one model. The current version of the model includes significant refinements in both spatial and temporal resolution while incorporating major wetland systems (e.g., WCA-1 and WCA-2A) along with a detailed representation of the Lake Worth Drainage District canal system. The model has been developed specifically to support the Central and Southern Florida Flood Control Project Comprehensive Review Study (Restudy), the subsequent Comprehensive Everglades Restoration Plan (CERP), and the LEC regional water supply planning process.

Model Domain

The model encompasses the portions of Palm Beach County and northern Broward County shown in **Figure F-5**. The northern boundary of the model is located along the M Canal, Clear Lake, and Lake Mangonia. The western boundaries of the active model area include the L-8 Canal, the L-7 Levee and Borrow Canal (WCA-1), the L-6 Levee and Borrow Canal (WCA-2A) and the L-38E Levee and Borrow Canal (WCA-2A). The southern boundary of the model traverses the L-35B Levee and Borrow Canal along with the C-14 Canal in Broward County. The eastern boundary of the model is located along the intercoastal waterway. A subset of the active model domain was defined where the model results of planning based applications could be used for decisionmaking purposes. This evaluation area of the model is shown in **Figure F-5**.

Horizontal and Vertical Discretization

The South Palm Beach model domain was discretized spatially into 430 rows and 324 columns using 500-foot square cells. The model is discretized vertically into five layers of varying thickness, with the wetland layer as the uppermost layer and the bottommost layer terminating at an elevation of –300 ft NGVD.

Physical Features

Hydrogeology

The SAS is an unconfined aquifer system recharged by rain, and by leakage from canals and other surface water bodies. Data from existing well logs were used to determine the aquifer extent and construct a conceptual hydrostratigraphic model. The top wetland layer is restricted to the extensive wetland systems within the model domain and includes WCA-1, WCA-2A, the Strazzulla Tract, and the Loxahatchee Mitigation Bank areas. It consists of ponded surface water, as well as the peat, sand, and caprock layers underlying the wetlands. The bottom elevation of the wetland layer varies from –10 to 5 ft NGVD. Layer two represents the sand and shell layers overlying the Biscayne aquifer, where the bottom elevation varies from –25 to –100 ft NGVD. Layers three and four represent the Biscayne aquifer, the most productive interval within the SAS. The Biscayne aquifer in southern Palm Beach County is also referred as the Zone of Secondary Porosity (Swayze and Miller, 1984) and is characterized by highly solutioned limestones with large hydraulic conductivities. The bottom elevation of the Biscayne aquifer within the model domain varies from –90 to –210 ft NGVD. The relatively large thickness of the Biscayne aquifer and the fact that most of the production wells are present in this zone made it desirable to subdivide this zone into two layers. The model layer below the Biscayne aquifer is comprised of the relatively less permeable sequences of clays, silts, and limestones of the Hawthorn group. It is also considered to be within the intermediate confining unit that lies between the SAS and the Floridan aquifer. The bottom of this layer was set at a constant elevation of –300 ft NGVD since there were not enough data to clearly demarcate the transition from the SAS to the intermediate confining unit.

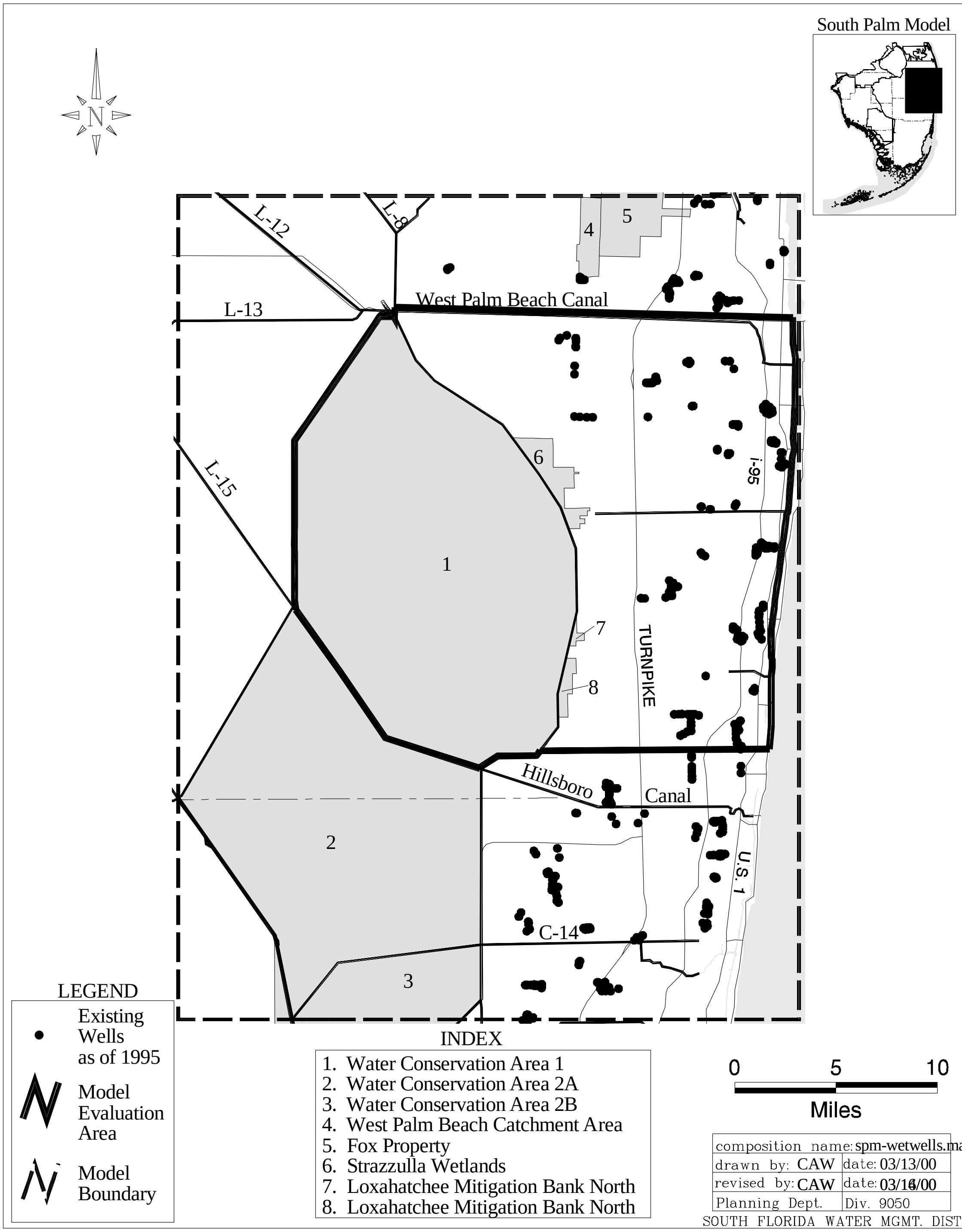

Figure F-5. Model Boundaries and Major Features of the South Palm Beach County Ground Water Flow Model.

The hydraulic properties of the SAS were estimated in part through Aquifer Performance Tests (APTs) performed by the USGS, SFWMD, U.S. Army Corps of Engineers (USACE), and independent consultants. In addition, specific capacity tests, lithologic correlations and geophysical logs were used, where applicable, to estimate the hydraulic properties.

Recharge and Evapotranspiration

The models used to simulate recharge and evapotranspiration are discussed in the General Subregional Model Features section earlier in this appendix. The stations used for the South Palm Beach County Ground Water Flow Model are presented in **Figure F-6**.

Surface Water Management

Within the model domain is an extensive network of surface water management systems that have a significant effect on the ground water (**Figure F-5**). The District canals incorporated into the model include the C-51, C-15, C-16, Hillsboro, and the C-14. In addition, the model incorporates the numerous surface water management systems operated by independent drainage and water control districts. These include the Lake Worth Drainage District, the Acme Improvement District, the Loxahatchee Groves Water Control District, the Indian Trail Improvement District, and the West Palm Beach Water Catchment Area south of the M Canal in Palm Beach County. The water control districts within Broward County include the North Springs Improvement District, the Pine Tree Water Control District, the Cocomar Water Control District, Water Control District 2, Sunshine Drainage District, Coral Springs Improvement District, Turtle Run Drainage and Improvement District, Coral Bay Control and Drainage District, and Water Control District 3. Data regarding the operations of the independent drainage districts were compiled from a variety of sources including the system operators, SFWMD permit files, aerial photographs, field inspections, and real estate (REDI) maps.

The interaction of the canal network with the aquifer was modeled using the River and Drain packages. The canals were classified as rivers or drains depending on whether they were maintained or only used to drain the aquifer. For both cases, model input included canal stages and values for a conductance term defining the degree of interaction between the canal and the aquifer. Measured water levels at stage monitoring stations were used to define the hydraulic grade line elevations.

Wetlands

The largest wetlands in the model domain are WCA-1 and WCA-2A. Also included in the model as wetlands are the Strazzulla Tract and the Loxahatchee Mitigation Bank areas that form a buffer between WCA-1 (Loxahatchee National Wildlife Refuge) and the developed areas to the east. WCA-1 has an area of 227 square miles. The vegetation in WCA-1 consists predominantly of wet prairies, sawgrass prairies, and aquatic slough communities along with tree islands which are interspersed throughout the area. WCA-2A has an area of 173 square miles with vegetation cover types consisting of open water sloughs, large expanses of sawgrass intermixed with cattail, and drowned tree

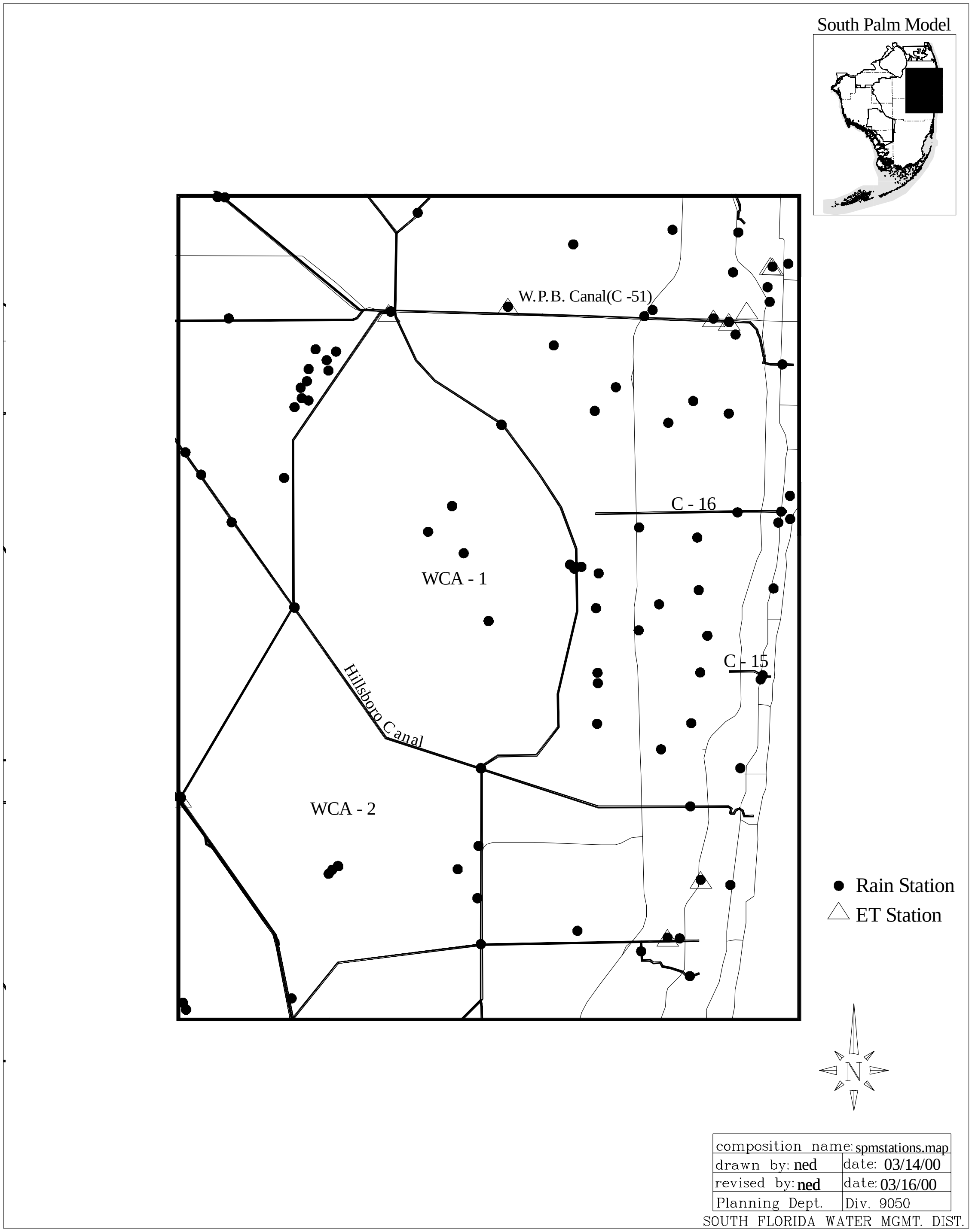

Figure F-6. Rainfall and Evapotranspiration Station Locations used in the South Palm Beach County Ground Water Flow Model.

islands dominated by willow. The Strazzulla Tract contain the only remaining cypress habitat in the eastern Everglades and one of the few remaining sawgrass marshes adjacent to the coastal ridge. The Loxahatchee Mitigation Bank wetlands are located south of the Strazzulla Tract. The spatially varying vegetative cover was accounted for in the Wetland package by the use of vegetative resistance coefficients.

The Wetland package (Restrepo et al., 1998) was the customized MODFLOW package used to simulate overland flow within the wetland areas of the model. The wetland model conceptualizes these areas as isolated wetlands with user specified inflows or outflows. The West Palm Beach Water Catchment Area located south of the M Canal was not modeled as a wetland since it is not only located outside the evaluation area for this model, but it its also adjacent to the model boundary.

Both WCA-1 and WCA-2A were modeled using the diversion option of the Wetland package. For purposes of computational stability the net inflow (difference between the inflows and outflows through the structures of each WCA) was applied uniformly over all the cells of each WCA for each time step. The Strazzulla Tract and Loxahatchee Mitigation Bank areas were modeled as wetlands having no structural inflows or outflows.

Water Use

The locations and attributes of PWS wells were obtained from the District's Water Use and Permits Division and modified to reflect current information. Monthly public water use was extracted from utility reports submitted to the District as a part of the permit limiting conditions. Also included in the reports were the well depths and the casing intervals. Based on this information, along with the percentage allocation among the different wells within each permit, average daily pumpages were assigned to each well in the model data sets. The pumpage was distributed between the model layers based on the layer transmissivities as outlined by McDonald and Harbaugh (1988).

Model Calibration

History matching was performed for two periods of record: a relatively dry period from June 1, 1988, through June 30, 1989, and a relatively wet period from June 1, 1994, through June 30, 1995. Both the history matching periods were preceded by a two-month warm up period in order to help minimize the effects of initial conditions on computed water levels.

The South Palm Beach Ground Water Model was calibrated under both steady state and transient conditions. The transient calibrations completed so far were restricted to history matching of heads and the model was considered to be calibrated at a given well location if the absolute value of the difference between the observed and the computed water levels was less than 1.0 feet for at least 75 percent of that portion of the calibration period of record where data was available. Since most applications of the model involved transient runs, the transient calibration results are reported here.

A total of 37 USGS and SFWMD water level gages were used in the wet calibration period while a total of 24 gages were available for the dry calibration period. The wet period has more observation wells available since some of the District gages in WCA-2 became operational only in late 1994. The locations of all wells and staff gages used for the calibration of the model are given in **Figure F-5**. Although the USGS observation wells have recorders that record the hourly water levels for each day, only the daily maximums are processed and stored in the USGS Automated Data Processing Systems (ADAPS) database. Hence, these ground water levels (as opposed to end-of-day water levels) were the only ground water level data available for history matching.

The transient calibration results are shown in **Table F-5** for the wet period of record and in **Table F-6** for the dry period of record. The tables show the percentage of time that the calibration criterion cited above was met. Also shown in the table are the mean error, or bias, and the standard deviation of the residuals.

A comparison of the two calibration periods of record show that, in general, the model performs better during the wet season than in the dry season. This is especially true in the wetland areas. The results also show that while all of the gages in the WCAs met the calibration criteria for the wet period of record, only two of the five gages met the criterion during the dry period of record when the water levels were below open land surface. Apparently, simulations of wetland stages are fairly accurate when the water levels are above land surface and there is overland flow. It is possible that when no overland flow exists the uncertainties inherent to characterization of the shallow wetland geology result in an under prediction of heads in the wetland layer.

Shortcomings in both the model itself and the water level data prevented calibration targets from being met within certain areas. For example, in the urban areas, it is apparent that the model does not meet the calibration criteria in southeastern Broward County. This is at least partially due to the fact that the operational criteria of the secondary canals within this area cannot be adequately represented by the River and Drain packages. Also, the proximity of observation wells to local stresses sometimes precludes the use of their data for history matching with a finite-difference model. For example, the model was consistently overpredicting water levels at the well PB-1491, which is within the city of Boca Raton's wellfield. In addition, several of the observation wells had suspected errors in their measuring point elevations. Some of these were corrected or verified while others could not be addressed since the observational wells are no longer in service. Also, limitations in boundary conditions can affect model results at sites located near the boundaries.

Perhaps one of the most significant obstacles to achieving calibration goals was posed by the somewhat inappropriate nature of much of the available water level data. As mentioned earlier, the historical ground water levels currently available from the USGS database are daily maximum values. In contrast, the model computes the heads for the end of each day. Significant differences can exist between daily maximum and end-of-day ground water levels. Also, most of the canal stage data available for the Lake Worth Drainage District, a large portion of the model domain, are only spot measurements and not the mean daily stages that should be used for model input.

Table F-5. South Palm Beach County Calibration Statistics for the Wet Period (June 1, 1994, through June 30, 1995).

Gage Name	Percent Within One Foot	Mean Error (feet)	Standard Deviation Error (feet)	Within Evaluation Area	Comments
PB-809	92.9	-0.329	0.462	N	
PB-99	99.7	-0.085	0.508	N	
PB-1639	53.7	-1.181	0.819	Y	
PB-1491	2.8	2.918	1.009	Y	Boca Raton Wellfield
PB-732	96.5	-0.425	0.324	Y	
PB-1684	94.7	-0.338	0.269	Y	
PB-1661	92.2	-0.343	0.420	Y	
PB-900	79.6	0.571	0.542	Y	
PB-561	73.8	-0.796	0.642	N	
PB-683	79.8	-0.595	0.490	Y	
PB-1680	89.2	0.551	0.365	Y	
PB-685	83.8	-0.034	0.690	N	
PB-445	97.0	-0.148	0.506	Y	
G-1260	43.0	-0.965	1.209	N	Southeast Broward County
G-2739	85.8	0.457	0.567	N	
G-1213	85.9	-0.302	0.783	N	
G-1315	61.5	-0.318	1.049	N	Southeast Broward County
G-1215	27.3	-1.197	2.100	N	Southeast Broward County
G-2031	98.1	-0.092	0.314	N	
G-2147	25.7	-1.717	1.106	N	Southeast Broward County
G-1316	98.9	0.306	0.357	N	
G-853	55.0	-0.756	1.330	N	Southeast Broward County
G-616	94.1	0.019	0.623	N	
1-9[a]	100.0	0.083	0.301	N	
1-8T[a]	100.0	0.098	0.314	N	
1-7[a]	100.0	0.199	0.238	N	
2-17[a]	100.0	0.072	0.189	N	
2-19[a]	76.6	-0.723	0.848	N	Southeast boundary of WCA-2
2A-300_B[a]	100.0	-0.234	0.227	N	
2A-17_B[a]	100.0	0.065	0.194	N	
2-15[a]	100.0	0.118	0.334	N	
WCA2RT[a]	100.0	-0.105	0.169	N	
WCA2F4[a]	100.0	0.064	0.197	N	
WCA2E4[a]	100.0	-0.066	0.219	N	
WCA2E1[a]	95.6	-0.123	0.408	N	
WCA2F1[a]	95.6	-0.206	0.385	N	
WCA2U1[a]	100.0	0.120	0.195	N	

a. USGS and SFWMD Gages in the WCAs

Table F-6. South Palm Beach County Calibration Statistics for the Dry Period (June 1, 1988, through June 30, 1989).

Gage Name	Percent Within One Foot	Mean Error (feet)	Standard Deviation Error (feet)	Within Evaluation Area	Comments
PB-561	69.4	0.062	1.051	N	
PB-809	93.4	-0.453	0.366	N	
PB-99	92.9	-0.620	0.296	N	
PB-683	82.3	-0.500	0.591	Y	
PB-445	97.5	-0.403	0.332	Y	
PB-900	72.7	0.794	0.767	Y	
PB-1491	0.0	7.348	1.502	Y	Boca Raton Wellfield
PB-732	98.0	-0.044	0.433	Y	
PB-88	89.4	0.149	0.675	Y	
PB-1495	15.7	1.322	0.351	Y	May have survey problems
G-1260	76.2	0.374	0.700	N	
G-1213	50.9	0.405	1.061	N	Southeast Broward County
G-1315	46.3	-0.906	1.029	N	Southeast Broward County
G-1215	51.4	0.425	1.126	N	Southeast Broward County
G-2031	95.7	0.444	0.482	N	
G-2147	74.7	-0.508	0.675	N	
G-1316	98.0	-0.362	0.299	N	
G-853	19.8	1.942	0.950	N	Southeast Broward County
G-616	46.0	-1.512	1.061	N	Southeast Broward County
1-9[a]	95.7	-0.616	0.298	N	
1-8C[a]	71.1	0.574	1.035	N	
1-7[a]	65.3	0.364	0.849	N	
2A-300_B[a]	6.1	-1.885	0.462	N	South boundary of WCA-2
2A-17_B[a]	87.1	-0.047	0.698	N	

a. Gage is in the WCAs where water levels were below land surface part of the time.

Conclusions and Recommendations

Model Capabilities and Limitations

The ground water model developed simulates the hydrogeology of the SAS within southern Palm Beach County, as well as the overland flow in the wetland systems. However, the current version of the model has been calibrated only with respect to water levels. The model has not been calibrated for base flows due to resource limitations. This limitation of the model should be kept in mind while evaluating canal base flow or ground water flow across selected boundaries. Consequently, stage duration curves for wetlands and water level hydrographs used for comparative type analysis are the primary type of hydrologic performance measures that the model is capable of supporting.

In addition to the caveats mentioned above, it should be emphasized that the eastern boundary of the model is based on a simplistic representation of the saltwater-freshwater interface within the SAS. The characteristics, position, and movement of this interface are all based on complex factors and principles (e.g., density-driven flow) that cannot be readily incorporated into a ground water flow model that only accounts for freshwater flow. Consequently, the model cannot directly support any performance measures that relate to, or are contingent upon, the shape, position, or movement of the saltwater wedge that, in reality, constitutes the eastern boundary of the ground water flow system.

Future Improvements

The model shall be improved in the future to address the following:

- Sensitivity and uncertainty analysis of all model parameters to improve the overall model calibration
- Acquire the necessary data and resources to calibrate the model for base flows
- Sensitivity analysis of the wetland model parameters to understand the dynamics of the wetland aquifer interactions when the water level goes below the land surface
- Addition of new packages which will incorporate the recharge/ET computations into the simulation model and avoid the use of preprocessed values
- Resolve the discrepancies with the USGS associated with monitored daily maximum values and the model computed end-of-day values
- Formulate cooperative agreements with the secondary water control districts to improve the data collection efforts for stage monitoring
- An improved representation of the saltwater-freshwater interface located along the coastal boundary